International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249-6890; ISSN (E): 2249-8001
Vol. 9, Issue 4, Aug 2019, 671-676

SHEAR STRESS ANALYSIS IN PALM KERNEL SHELL REINFORCED BRAKE LININGS

R. S. FONO-TAMO & JOHN Y. PUMWA

Department of Mechanical Engineering, Papua New Guinea University of Technology, Lae, Papua New Guinea

ABSTRACT

The load applied to the pad during breaking to slow the moving vehicle tends to cause shear in the pad material as it rubs on the disc surface. Depending on the nature and composition of the pad material, the load application and the resulting shear stress can cause considerable changes in the structure of the pad due to the elevated temperature arising from the friction process. This work focuses on estimating the shear stress of an organic brake lining using Matlab PDE Toolbox and propose the best particle size for palm kernel shell (PKS) based friction lining manufacture. To achieve this, properties of organic brake lining developed using various particle sizes (0.212, 0.300, 0.425 and 0.600 mm) of PKS powder as reinforcement were determined in order to be used in a partial differential equation suitable to be processed in Matlab. Under shear stress and at elevated temperature, all the materials presented a considerable percentage of volume loss. $S_{0.300}$exhibited the least applied shear stress value of 3MPa and $S_{0.425}$ with the highest applied shear stress (4MPa), $S_{0.212}$ being closer to $S_{0.600}$ with 3.5 MPa. These values corresponded well with what is obtained in the literature.

***KEYWORDS:** Palm Kernel Shell, Friction Lining, Matlab PDE Toolbox & Shear Stress*

Received: Apr 29, 2019; **Accepted**: May 22, 2019; **Published**: Jul 08, 2019; **Paper Id**.: IJMPERDAUG201967

Original Article

INTRODUCTION

Shear stress tends to cause deformation of a material by slippage along a plane or planes parallel to the imposed stress. It is a stress state in which the shape of a material tends to change without particular volume change. A typical case is the work of Jalalv and et al. [1] where they analysed the energy dissipation during delamination in composite materials by doing an experimental assessment of the cohesive law and the stress-strainfield ahead of a crack tip. The work had to do with separating glass/epoxy and carbon/epoxy layers/planes and determine the stress involved in such process. They showed that at the lowest applied load of 428 MPa, the separation at both top and bottom interfaces are almost equal and that the volume remains finite. Evaluating material behavior under stress through simulation has been on the rise due to its cost and time saving avantage. Rana and Rathod [2]used ABAQUS/CAE 6.12 to simulate temperatures, shear and von-mises stresses as well as contact pressures values in five different materials of brake. Sarkar et al. [3] also used ABAQUS to analyse disc brake temperature distribution in a Cast Iron disc. Ali Belhocine et al. [4] used ANSYS 11 to simulate the thermal behavior of full and ventilated disc. Singh et al. [5] used COMSOL Multiphysics to analyse heat generation and dissipation in a disc brake during panic braking just to mention a few. Most of these authors focused on the disc while giving less attention to the pad. The Matlab PDE Toolbox has proven to be a good instrument for predicting material behavior. Ihueze et al. [6] used it to predict critical stresses of an automobile tire side wall.

This work seeks to predict the best suitable PKS powder size to be recommended for the development of organic friction lining based on shear stress characteristics by using the Matlab PDE Toolbox.

MATERIALS AND METHODS

The samples were developed accordingly as described by [7]where friction linings with various pulverized PKS grain sizes as reinforcement were produced. The properties of the developed samples useful for the analysis were determined as found in [8]. A mathematical model [9] describing the thermal stress distribution in the brake lining was in the form of a partial differential equation with the temperature at a position in the lining varying inversely with the cube root of its distance from the surface where braking force is applied. The developed model was then simulated in MATLAB. The modified Matlab problem geometry in Figure 1 was adopted and various assumptions taken into consideration to arrive at the mathematical model. Details are found in another publication.

$$L = \frac{\theta}{360}\pi(r_{out} + r_{in})$$

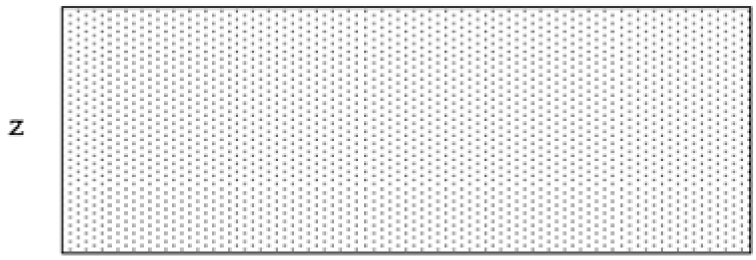

Figure 1

Using the Graphical User Interface and the PDE tool in it, the application mode was set to structural mechanics, plane stress. The Constructive Solid Geometry (CSG) model was made very quickly by using the determined values of *L* and thickness *t*. The rectangle was simply labeled R_1.

Boundary mode was next selected to specify the boundary conditions. All subdomain borders were first removed by selecting Remove All Subdomain Borders from the Boundary menu. The next step is to open the PDE Specification dialog box and enter the PDE parameters. The E and ν parameters are Young's modulus and Poisson's ratio, respectively. ρthe density was used in this mode as well. The material was considered homogeneous, so the values were imputed for each sample in the whole 2-D domain. The mesh was initialised by clicking the Δ button.

The problem was solved by clicking the = button. A number of different strain and stress properties can be visualized, such as the displacements u and v, the shear stress. All these properties were selected from pop-up menus in the Plot Selection dialog box. A combination of scalar and vector properties were plotted simultaneously by selecting different properties to be represented by color, height, vector field arrows, and displacements in a 3-D plot.

RESULTS AND DISCUSSIONS

The plots of shear stress from various PKS-based brake pads grain sizes give the value of the recorded shear stress when the load is applied. The colour code from the graph and the legend help to identify on which part of the sample the value is recorded. Fukumasu*et al*. [10] studied the stresses developed during the sliding of a cylinder over compact graphite iron by numerical analysis. ABAQUS software was used for the analysis. The colour scale indicated the stress values calculated at the areas of those figures. The finite element results were later compared with literature experimental

pin on disc results with compact graphite iron discs. Good agreement was obtained when numerical and experimental analyses were compared. Both methods indicated that the contact stresses result in significant amounts of plastic deformation in regions close to the disc surface. The analysis of shear stress in this study followed the same trend in that the colour scale indicated the stress values, plastic deformations were observed at the edges of the samples. The disadvantage of having material shrinkage being that thermally excited vibration may develop due to partial contact at the friction interface, twisting may lead to thermal cracks, excessive wear and eventually fracture of the friction material in the process of breaking.

Figure 2(a) shows significant material deformation in $S_{0.212}$. Shrinkage (volume loss) occurs in the general direction of shear stresses with downward crumpling at the left edge and upward twisting at the right edge. There are 216 unshaded boxes here with a total of (24 x 24) = 576 boxes. The Volume loss = Deformation = (216/576)*100% = 37.5% (approx.). Shear stress value is up to 3.5MPa. In $S_{0.425}$, as well, significant material deformation was identified. Shrinkage (volume loss) occurs in the general direction of shear stresses with downward crumpling at the left edge and upward twisting at the right edge. Unshaded boxes = 203 (approx.) and Total boxes = 24 x 24 = 576. Volume loss = Deformation = (203/576)*100% = 35.2% (approx.) and Shear stresses up to 4MPa was recorded as seen in Figure (c). $S_{0.300}$ presents significant material deformation. Shrinkage (volume loss) occurs in the general

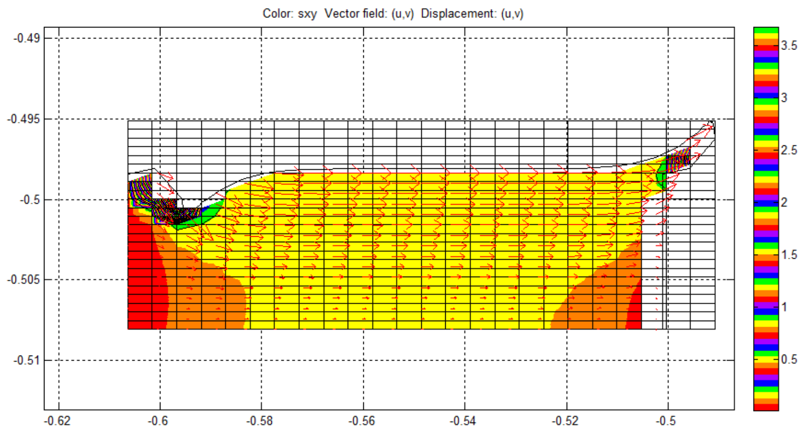

Figure 2(a): Impact of Shear Stress Plot for $S_{0.212}$

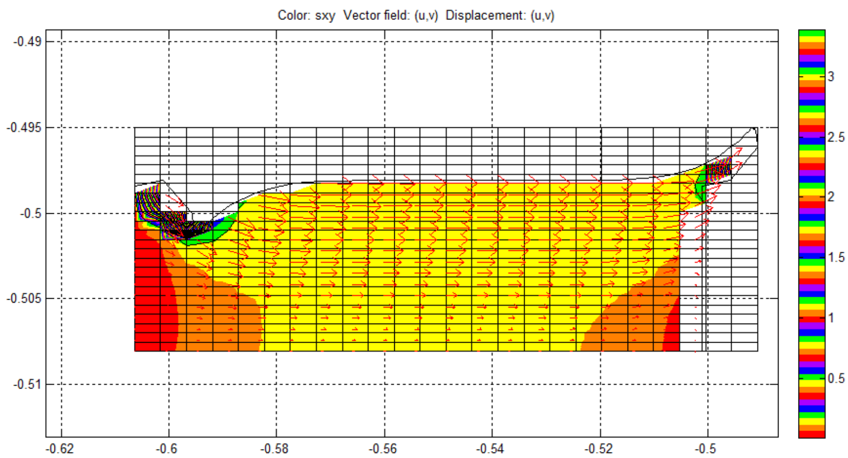

Figure 2(b): Impact of Shear Stress Plot for $S_{0.300}$

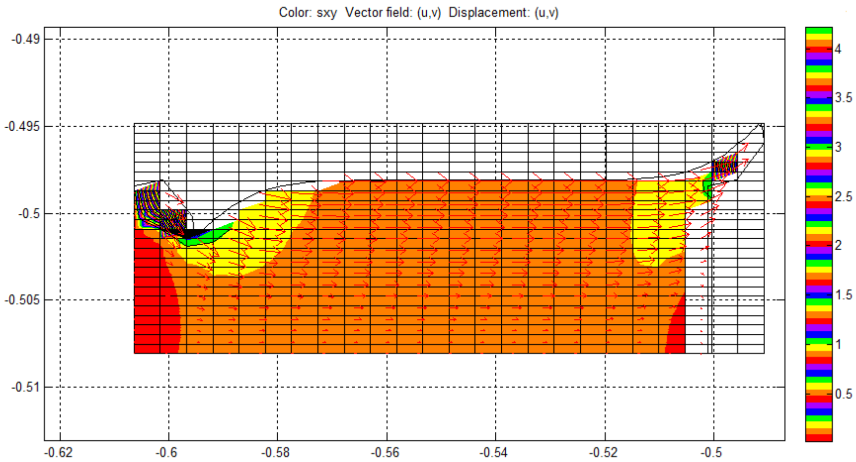

Figure 2(c): Impact of Shear Stress Plot for $S_{0.425}$

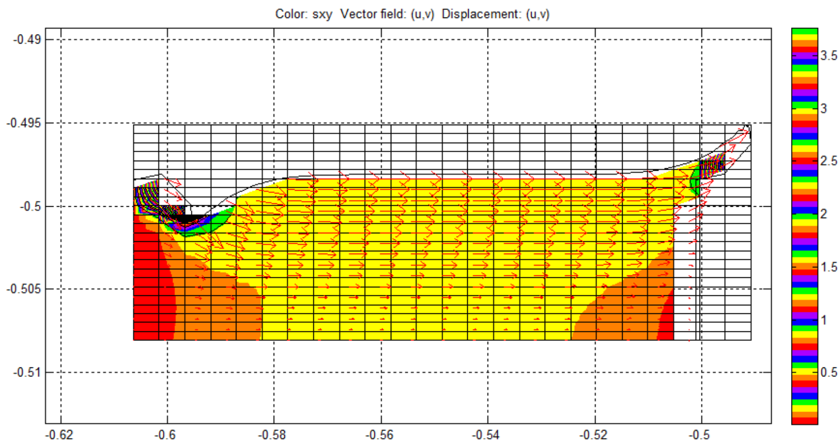

Figure 2(d): Impact of Shear Stress Plot for $S_{0.600}$

Direction of shear stresses with downward crumpling at the left edge and upward twisting at the right edge in Figure 2(b) Unshaded boxes = 203 (approx.), Total boxes = 24 x 24 = 576, Volume loss = Deformation = (203/576)*100% = 35.2% (approx.) and Shear stresses up to 3MPa was recorded. Significant material deformation was noticed in $S_{0.600}$. Shrinkage (volume loss) occurs in the general direction of shear stresses with downward crumpling at the left edge and upward twisting at the right edge. The deformations characteristics evident in Figure 2(d) where the unshaded boxes = 217 (approx.), Total boxes = 24 x 24 = 576, Volume loss = Deformation = (217/576)*100% = 37.6% (approx.), Shear stresses up to 3.5 MPa are registered. From the above value of shear stress, it is worth mentioning that $S_{0.212}$, and $S_{0.600}$ have the same shear stress value (3.5MPa), $S_{0.300}$ is 3 MP and $S_{0.425}$ is 4MPa respectively. These values fall well within the range of shear stress obtained by Rana and Rathod (3.042 – 5.810 Mpa) when they studied the coupled thermo-mechanical characteristics of five different disc brake systems. They concluded that grey cast iron exhibited better shear properties due to the least value (3,042 MPa) its associated pads exhibited. (Hohmann *et al*. [11] made a comparative study of contact analysis of drum brakes and disk brakes using ADINA. In the case of disc brake analysis, they derived shear stress as high as 1MPawithin 1 second of load application. Thermal cracking in disc brake was also analysed by Mackin *et al.* [12] and even though their work focused on drum brake alone, they recorded shear stress as high as 215MPa. From the foregoing, it can be observed that shear stress in brake disc is much higher than that in drum brake. This may justify the recorded high value of shear stress in this study. It is close to that value reported by [11]. From Figure 2(a), $S_{0.300}$ was the least affected. In general, all the material present a considerable percentage of volume loss this could be a serious disadvantage.

CONCLUSIONS

The analysis of shear stress field in PKS friction lining using Matlab is achievable. The obtained outputs are comparable with what found in the existing literature. From the current analysis, $S_{0,300}$with a shear stress value of 3 MPa exhibited a better shear property and thus is more stable than all the other samples. $S_{0.425}$ is the most affected with a shear stress value of 4 MPa. This can be attributed to the fact that smaller grain size contributed to the production of more dense and compact product where applied load had less effect than samples with higher grain sizes. Finer particles ($S_{0.212}$) may be prone to excessive wear. $S_{0,300}$may be classified as the best suitable grin size for developing PKS based brake lining.

ACKNOWLWDGEMENT

The authors appreciate the valuable support from the Global Excellence Stature (GES) fellowship of the University of Johannesburg, South Africa.

REFERENCES

1. *M. Jalalvand, G. C._el, J. D. Fuller, M. R. Wisnom, Luis P. Canal, Carlos D. Gonz_alez, Javier LLorca (2016):"Energy dissipation during delamination in composite materials – An experimental assessment of the cohesive law and the stress-strain field ahead of a crack tip," Composites Science and Technology 134, pp 115 – 124*
2. *S. S. Rana, and W. S. Rathod (2016):" Coupled Thermo-Mechanical Analysis of an Automobile Disc Brake, "International Journal of Engineering Science and Computing, Vol 6 (6), pp 7073 – 7077.*
3. *S. Sarkar, P. P. Rathod and A. J. Modi (2014):" Research paper on Modeling and Simulation of Disc Brake to Ayse Temperature Distribution using FEA, "International Journal for Scientific Research & Development, Vol. 2, Issue 03, pp. 491-494.*
4. *Ayoola, A. A., Anawe, P. A. L., Ojewumi, M. E., & Amaraibi, R. J. (2016). Comparison Of The Properties Of Palm Oil And Palm Kerneloil Biodiesel In Relation To The Degree Of Unsaturation Of Their Oil Feedstocks. International Journal of Applied and Natural Sciences, 5(3), 1-8.*
5. *A. Belhocine and M. Bouchetara (2012):"Thermo mechanical modelling of dry contacts in automotive disk brake," International Journal of Thermal Sciences 60, pp. 161-170.*
6. *H. Singh and H. Shergill (2012):" Thermal Analysis of Disc Brake using Comsol,"International Journal on Emerging Technologies, pp. 84-88.*
7. *C. C. Ihueze, C. O. Mgbemenaand A. R. R. Menon(2014); "2D static failure prediction for critical stresses of an Automobile Tire Side Walls using MATLAB PDE Toolbox, "IOSR Journal of Mechanical and Civil Engineering, Vol 11 (4), pp. 70-76*
8. *R. S. Fono-Tamo and O. A. Koya (2017):" Influence of Palm Kernel Shell Particle Size On Fade And Recovery Behaviour of Non-Asbestos Organic Friction Material". International Conference on Sustainable Materials Processing and Manufacturing (SMPM 2017), 23-25 January 2017, Kruger National Park, Procedia Manufacturing 7 (2016) 440 – 451*
9. *R. S. Fono-Tamo (2017):"Effect Of Particle Sizes On The Thermophysical Properties Of Palm Kernel Shell Based Brake Pads". 2017 8th International Conference on Mechanical and Intelligent Manufacturing Technologies (ICMIMT 2017), Cape Town, South Africa, 3-6 February 2017, Conference Proceedings published by IEEE.*
10. *Alavala, C. R. (2016). Effect of Temperature, Strain Rate and Coefficient of Friction on Deep Drawing Process of 6061 Aluminum Alloy. International Journal of Mechanical Engineering, 5(6), 11-24.*

11. *Fukumasu, N. K., Pelegrino, P. L., Cueva, G., Souza, R. M. and Sinatora, A. (2005):" Numerical analysis of the stresses developed during the sliding of a cylinder over compact graphite Iron". Wear 259:1400-1407.*
12. *Hohmann, C., Schiffer, K., Oerter, K. and Reese, H. (1999):" Contact analysis for drum brakes and disk brakes using ADINA". Computers and Structures, 72: 185 – 198.*
13. *Mackin, T. J., Steven, C., Noe, K. J. and Ball, B. C. (2002):"Thermal Cracking in Disc Brakes." Engineering Failure Analysis 9: 63-76.*